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ABSTRACT

This module is the fifth in a series of eleven modules in an energy conservation curriculum for secondary and postsecondary vocational students. It is designed for use by itself or part of a sequence of four modules on understanding utilities (see also modules 3, 6, and 7). The objective of this module is to train students to recognize energy-related factors in lighting, including differences in light bulbs and fixtures. First, an introduction to the module and definitions of key terms are provided. Next, the text is presented in the following three units: (1) lighting efficiency; (2) estimating lighting requirements; and (3) tips for better lighting efficiency. The information in each unit is presented in lecture format accompanied by laboratory exercises and questions/examples for class discussion. A bibliography and several charts illustrating the text material are found at the end of the module. (BM)

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Energy Conservation Curriculum for Secondary and Post-Secondary Vocational Students. Module 5.

LIGHTING CONSERVATION OPPORTUNITIES

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NAVARRO COLLEGE
CORSICANA, TEXAS

April, 1979

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NATIONAL INSTITUTE OF EDUCATION

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MODULE #5

LIGHTING CONSERVATION OPPORTUNITIES

This module is one of a group of 11 modules in an energy conservation curriculum for secondary and post-secondary vocational students. Lighting Conservation Opportunities may be offered by itself or as part of a sequence of three modules in the following order:

Order	Module	Title of Module
1	3	Understanding Utility Bills
2	5	Lighting Conservation Opportunities
3	7	Appliance Energy Conservation Opportunities

MODULE #5

LIGHTING CONSERVATION OPPORTUNITIES

MODULE DESCRIPTION:

The student will be introduced to the types of lighting fixtures used in residences and commercial buildings and will be able to compare them in terms of energy usage, light output (that is foot candles or lumens per watt), and heat output. Discussion will include the required lighting levels for certain tasks and activities, color definitions, and time elements for usage. The survey of conservation opportunities in lighting will include an analysis of cost and benefits in energy used or saved. The module concludes with suggested implementation of lighting conservation opportunities.

GOAL STATEMENT:

The objective of this module is to train secondary and post-secondary students to recognize energy-related factors in lighting, including differences in light bulbs and fixtures. Further, it is to enable the student to implement conservation techniques for lighting use in both residential and commercial settings.

MODULE #5

LIGHTING CONSERVATION OPPORTUNITIES

TERMINOLOGY

ballast - an electrical resistance device which maintains nearby constant current by increasing in resistance as the current increases.

British thermal unit (BTU) - a unit of heat energy equal to the heat needed to raise the temperature of 1 pound of air-free water from 60° to 61° F at a constant pressure of 1 standard atmosphere.

cathode - the primary source of electrons in an electron tube; in directly heated tubes the filament is the cathode.

fluorescent - a tubular discharge lamp in which ionization of mercury vapor produces radiation that activates the fluorescent coating on the inner surface of the glass.

footcandle - a unit of illumination, equal to the illumination of a surface, 1 square foot in area, on which there is a luminous flux of 1 lumen uniformly distributed, or equal to the illumination of a surface all points of which are at a distance of 1 foot from a uniform point source of 1 candle intensity.

incandescent lamp - an electric lamp that produces light when a metallic filament is heated white-hot in a vacuum by passing an electric current through the filament.

kilowatt-hour - a unit of power equal to 1000 watts; equals about 3,400 BTU's.

lumen - the unit of luminous flux, equal to the luminous flux emitted within a unit solid angle by a uniform point source of one candle intensity.

phosphor - a luminescent material that converts part of the absorbed primary energy into emitted luminescent radiation.

watt- unit of power equal to the rate of work represented by a current of one ampere under a pressure of one volt and taken as the standard in the U.S.: 1/746 horsepower.

UNITS:

1. Lighting Efficiency
   - A. Use Fewer Bulbs to Save Money
   - B. Lamp Life
   - C. Fluorescent Lights
   - D. Lights Produce Heat Energy
2. Estimating Lighting Requirements
3. Tips for Better Lighting Efficiency

MODULE #5

LIGHTING CONSERVATION OPPORTUNITIES

UNIT 1

LIGHTING EFFICIENCY

OBJECTIVES: At the completion of this unit the student will be able to:

1. Distinguish the characteristics of incandescent and fluorescent light bulbs and fixtures.

2. Discuss the relative efficiency of incandescent, incandescent long-life, and fluorescent bulbs.

3. Discuss lamp life differences among various types of light bulbs.

4. Discuss the various types of fluorescent bulbs, their uses, and characteristics.

5. Explain the advantages and disadvantages of lamp heat produced by various bulb types.

LECTURE

INTRODUCTION

The total national energy cost in the United States in 1975 was $170 billion. This amount has more than tripled, in recent years. Industry in our country uses 36 percent of this energy, commerce about 11 percent, and residences about 26 percent. Of the total household energy used annually, lighting accounts for 16 percent of that usage. (See Figure 1.1) That means the average home uses over 2000 kilowatt-hours of electrical energy each year simply for lighting. Your local electric plant burns about 150 gallons of oil or over 3/4 tons of coal to generate that amount of electricity.

LABORATORY

1. Acquire the present cost to the consumer of one kilowatt-hour of electricity in your area. Multiply that by 2000 to establish your annual expense for lighting. Multiply the answer by the estimated number of residents in your town. Is the figure surprising?

2. Find out the price paid for a barrel of crude oil by your electric plant. Multiply that by 3. (One barrel of oil is 55 gallons. One hundred fifty gallons of oil represent approximately 3 barrels.) This is the cost per residence the electric company incurs for generating energy for lights.

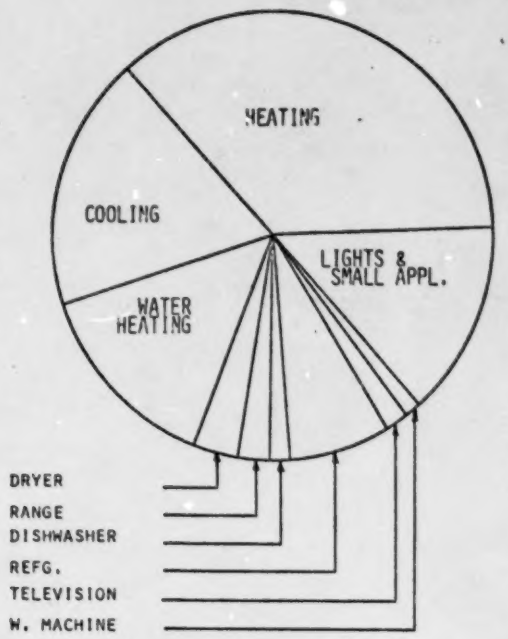
gallons of oil or over 3/4 tons of coal to generate that amount of electricity.

Light energy is important but the number of lights and the types of lighting fixtures used vs. those required for certain activities greatly effect your electric bill and the efficiency return for the energy spent. In other words, not all light bulbs and light fixtures are equal.

What is the percentage of mark-up between the cost for the oil to the electric company and the cost to the customer for lighting energy?

3. Calculate the above figures for coal. If coal is not used in your area today to generate electricity, but is available for such use, what would the difference be in using coal vs. oil to produce the same amount of electricity?

FIGURE 1.1
AVERAGE ANNUAL KWH BY APPLIANCE



SOURCE: Texas Power and Light Company

Some lights give off much more light energy than others, even though they consume the same amount of electricity. For instance, two 60-watt bulbs actually give off less light than a single 100-watt bulb. Or one 40-watt fluorescent bulb produces almost as much light as two 100-watt incandescents while using less energy. Therefore, your choice of lighting fixtures and bulbs can have a very significant effect on your electrical bill.

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Figure 1.2 gives the light output of various lamps. The unit of light energy output is the lumen -- the more lumens a lamp produces, the more light you will have. But the number of lumens is only one side of the story. Lamps are powered by electricity, so what you are most interested in is the number of watts required to produce the desired amount of light. A measure of the efficiency of a light source is the ratio of lumens to watts. Figure 1.2 shows that small incandescent lamps are less efficient sources of light than larger lamps. Note, however, that fluorescent lamps are much more efficient than incandescent lamps. In fact, a 40-watt fluorescent bulb gives off more than seven times as much light as a 40-watt incandescent.

FIGURE 1.2. ENERGY EFFICIENCY OF VARIOUS LAMPS

WATTS	LUMENS	LIFE (HOURS)	(LUMENSWATT)
Incandescent Lamps			
40	435	1500	10.9
60	840	1000	14.0
75	1140	750	15.2
100	1710	750	17.1
150	2740	750	18.3
200	3940	750	19.7
Three-Way Incandescent Lamps			
50-100-150	560-1630-2190	1200	11.2-16.3-14.6
50-200-250	550-3560-4110	1200	11.0-17.8-16.4
100-200-300	1290-3440-4730	1200	12.9-17.2-15.8
Fluorescent Lamps (Cool White)			
15 (T8)	870	7500	58.0
15 (T12)	770	7500	51.3
20	1220	7500	61.0
22 (Circline)	950	7500	43.2
30	2340	15000	78.0
32 (Circline)	1750	7500	54.7
40	3120	15000	78.0
75	6200	12000	82.7

A. USE FEWER BULBS TO SAVE MONEY

The trend today in lighting fixtures is to use several low-wattage bulbs instead of one or two larger bulbs. Admittedly, this may make some lighting fixtures more attractive than others, but they do not use electricity as efficiently. For example, a ceiling fixture with four 40-watt bulbs, at an energy

Survey your home or school. Note the number of light bulbs in each room, the wattage of each, and whether they are of regular or long-life variety.

Are all the bulbs used at the same time?

usage cost of 4 cents per kilowatt-hour, this fixture will use up to $18.69 of electricity per year if it is on for 8 hours a day. On the other hand, if you take out the 40-watt bulbs and use just two 60-watt bulbs, The lighting fixture will give off the same amount of light, but will cost only $14.02 per year to operate -- a savings of $4.67.

An additional savings comes about as you replace the bulbs that burn out during the year. If the fixture is on 8 hours a day, this amounts to just under 3000 hours a year. Presently, 40-watt bulbs have an average life of 1500 hours, compared to the 60-watt bulbs, which last only 1000 hours. But don't let this fool you! If you use 40-watt bulbs, you would have to replace all four bulbs twice each year, which would mean buying eight bulbs. If you used 60-watt bulbs, even though you would have to replace them three times during the year, you would still only have to buy a total of six bulbs, which would save you the price of two bulbs each year. Using one 100-watt bulb to replace four 40-watt bulbs would save you $7.01 plus the price of four bulbs per year. Your savings would be even greater if your requirement was to burn the lights longer each day, thus shortening their life.

B. LAMP LIFE

The life expectancy of any bulb is shortened a little each time you turn it on. In an incandescent bulb, the initial surge of current presents quite a shock to the filament inside. If you stop to think about it, you may note that most bulbs seem to burn out just as you turn them on. When manufacturers calculate the average

Are there pairs of bulbs doing the job that one bulb of higher wattage could do?

Using the formula in the example, compute how much money the duplication of bulbs versus replacing the bulbs with higher wattage could be realized in one year.

Using the examples in the text and the information gathered in the exercise above, do you see places in each room where the wattage of the bulbs --not the number of bulbs --could be reduced without losing effectiveness of that particular fixture?

What savings could you realize by replacing the wattages of these bulbs?

For three days, take note of the routine you follow when entering and leaving certain rooms in your home.

Do you consistently turn off lights when leaving a room?

How many times are lights turned off and on in certain rooms?

life of a bulb, they have to estimate how often the bulb will be turned on during its lifetime. If the bulb were only turned on once, and left on, the bulb would probably burn several times as long. On the other hand, if you turn the lights on and off dozens of times each day, the life expectancy of the bulbs will be shortened greatly because electric light is produced by heating the filament in the bulb to a high degree in order for it to glow.

One controversy which has been debated for some time is whether one should turn off a light when leaving a room for only a short while. It is argued that the amount of electricity required during the surge when a bulb is turned on is greater than the electricity used to keep it on for a short period. The point is, however, not in the tiny amount of extra electricity that is consumed during the surge when the bulb is turned on, but in the extent to which the life expectancy of the bulb is reduced.

If you figure what the bulb would cost to replace, and weigh that against the small amount of electricity it would consume by being left on a few minutes, you will find that the cost of turning on the bulb is roughly equal to the cost of electricity it uses in five minutes. In other words, if you turn a bulb off for less than five minutes, you will save some electricity, but in the long run you will lose more money by having to replace the bulb sooner. This is one instance in which you can actually save money by wasting a little energy.

What is the time interval beteen the number of times a light is used, then turned off, then turned on again?

Can you estimate the life expectancy of these bulbs as short, moderate, or long, based on use?

Would a change in your routine lengthen the life of these bulbs?

Discuss the pro's and con's of leaving a light on or turning it off in your particular case, based on the information you gathered in your survey above.

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The life of bulbs has received so much attention that manufacturers have developed "long life bulbs." It is claimed that these bulbs last several times as long as regular bulbs. It is true that they do last longer, but they do not give off as much light. The lumen output is printed on the package of each bulb. These bulbs last longer because the filaments do not get as hot, which means they do not give off as much light compared to regular bulbs. Ironically, manufacturers charge a higher price for these long-life bulbs. Therefore, in the long run, the long-life bulb is a questionable bargain. If the bulb is needed in hard-to-reach places, such as stairwells and on high ceilings, it will be advantageous to install a long-life bulb for convenience of replacement.

As noted in Figure 1.2 fluorescent bulbs last considerably longer than incandescent types. The life expectancy of these bulbs is usually calculated for industrial users who turn on the lights in the morning and leave them on until night. Fluorescent bulbs have filaments (called cathodes) at each end of the bulb to help the flow of current through the bulb. These filaments are heated slightly, but do not produce much light. Contrary to popular belief, most modern rapid-start fluorescent tubes do not require surges of electricity when first turned on, and most tubes will not burn out faster as a result of frequent on-off-on cycles, which was a problem with older type fluorecent tubes.

Bring in light bulb packages from "long-life" bulbs and regular bulbs. Compare their life expectancy and lumen output.

What have you learned?

What type do you use in your home?

Based on what you have just studied, are you getting the most for your money in using your particular bulbs?

C. FLUORESCENT LIGHTS

Factories, offices, and stores use fluorescent lighting for one reason -- to save money! Although fluorescent fixtures typically cost two or three times as much as comparable incandescent fixtures, the savings in electricity will normally pay for the difference in less than two years. From then on fluorescent lighting costs far less than incandescent lighting. Figure 1.3 compares the advantages and disadvantages of using fluorescent lights vs. incandescent bulbs.

FIGURE 1.3. CHOOSING A LIGHT

	Incandescent	Fluorescent
Energy Use	Less efficient, produces more heat than light: 95% heat, 5% light.	Over 4 times as efficient as incandescent and lasts 7-10 times longer: 30% light, 70% heat.
Cost	Initial costs are less than fluorescent lighting.	Operating costs are less.
Versatility	Light can be adjusted by interchanging different wattage bulbs. Gain flexibility by using three-way bulbs and multiple switch controls.	Usually are stationary, ceiling-type fixtures that provide diffused lighting.
Best Use	For specific, close-in lighting: study, sewing room, bedroom, living room, or any area that requires light for reading and writing.	For general lighting: large work areas, bathrooms, laundry room, basement, kitchen, hallways, stairways, recreation rooms, or any large room where diffused light is required.

Source: Center for Science in the Public Interest

People expect fluorescent lights to be used in factories, hospitals, and industries, but they do not accept their use as readily throughout the home. There are two reasons suggested for this unacceptance: (1) fluorescent bulbs give off a "cold" white light or blue haze unlike incandescent warm yellow; (2) the box-like shapes of fluorescent fixtures do not have the "character" of versatility in design which incandescent fixtures can have.

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The light produced by a fluorescent bulb is determined primarily by the mixture of phosphors used to coat the inside of the bulb. The most common phosphor mixture is called cool white (CW), and this is the type used in most factories, offices, and stores. Colored phosphors, such as red, blue, yellow, and green, are used in many advertising signs. Other special phosphor mixes are used to make bulbs for growing plants indoors, which produce a light similar to true sunlight. The point is there are other choices besides cool white if this makes your home feel like an office building.

Incandescent lamps give off a light that is somewhat yellowish in color. Putting a CW fluorescent bulb in the same room with an incandescent just accentuates this difference. Many people find the clash objectionable. They may tolerate CW bulbs in their kitchen or bathrooms, but they do not want them in their living rooms. However, there are warm white (WW) bulbs available from most electrical supply stores. These bulbs give off a yellowish light similar in color to incandescent light. WW bulbs are rarely found in department and discount stores. People seem to be unaware of their existence.

Manufacturers also make fluorescent lights using a deluxe phosphor mixture. Regular phosphors suffer from the fact that they do not produce a balanced spectrum of light energy. They produce a

An interesting exercise might be for students to try to find these various fluorescent bulbs in your city. It may be surprising to find the limited supply of certain types, if you are able to find them at all.

What type of store handles each variety found? (Discount, electrical supply, commercial supplier, lighting shop, electrical contractor, etc.)

Take note in your home of where you have used fluorescent lighting. Can you indicate places where you might consider replacing incandescent fixtures with fluorescent ones?

lot of light energy containing blues and greens but lacking in reds and oranges. All colors in the light spectrum do not have to be present to make "white" light. There must be a sampling of colors blended in the right proportions. Manufacturers have created cool white deluxe (CWX) and warm white deluxe (WWX) bulbs that balance the color spectrum by adding more reds and oranges. The CWX bulb still produces a light that "looks" just as white as a regular CW bulb, but if a bright red cloth is held under the two lights, there will be an immediate difference. The red cloth will look drab and dull under the CW bulb, but it will be truly bright under the CWX bulb. The WWX bulb produces even more reds and oranges, giving the bulb a slightly pinkish appearance when placed next to a CW bulb. The "warm" light produced by the WWX bulb makes it attractive for use in the living areas of the home. Deluxe phosphors are even harder to find in stores.

Decorating with fluorescent fixtures is a harder problem to overcome because of their inherent "boxy" appearance. The most economical size fluorescent bulb to buy is the four-foot 40-watt type since this is the size used by the millions in offices and stores everywhere. Lighting fixtures using these bulbs are also quite inexpensive compared to other sizes. Most fixtures contain one, two, or four bulbs; the most common being the two-light "rapid-start" fixture. Two-light fixtures are now coming in an increasing number of styles suitable for the living areas of the home. There are traditional

What reasons would you have for not replacing incandescent fixtures with fluorescent fixtures? (They do not go with the decor or period theme of a particular room or house, etc.)

There are traditional white enamel fixtures for a kitchen, utility room, or other work area, or ones where the trim can be painted in any color desired. There are also prepainted fixtures, in bright colors, and fixtures with wood-grain trim. Office supply stores often carry a much lower selection of good-looking fluorescent fixtures than most department stores. Most fixtures have plastic covers to diffuse the light; acrylic covers are more desirable than polystyrene because they do not yellow or crack with age. Fluorescent fixtures cost more to manufacture and therefore cost more to buy than similar incandescent fixtures. Fluorescent fixtures use less electricity, however, and will pay for themselves in a short time. A 100-watt incandescent light bulb consumes 1 kilowatt-hour of energy every 10 hours. This is the same amount of energy needed to lift a 150-pound person 17,700 feet into the air. If this amount of energy can be cut down, think of the energy savings realized.

To illustrate the savings that can be obtained with a fluorescent fixture, consider a kitchen where the light will be on for a good part of the day. For a moderately large kitchen with a dining area, an incandescent fixture having four 75-watt bulbs would be needed to provide a good working light. Assuming that the lights are on for 8 hours each day and electricity costs 4 cents per kilowatt-hour, this incandescent fixture would cost $35.04 per year to operate, plus the cost of 16 bulbs, which would bring the total cost to about $43 per year. On the other hand, a twin-light rapid-start fixture containing two 40-watt fluorescent bulbs would require only about 95 watts to run. (The fixture's ballast transformer and lamp filaments would require about 15 watts.)

Using the formula in the example, compute the possible savings in operating costs you might realize if you were to replace an incandescent fixture in your survey with a fluorescent fixture.

The fixture would produce 37% more light, but it would use only $11.10 of electricity during the year. The bulbs, costing only about $3 for both, would last for several years before they needed replacing, so their cost would average less than $1 per year. In this case, the cost difference amounts to about $31 per year--it would not cost much more than that to buy a good-quality fixture. Thus, after the first year, the fixture would have almost paid for itself, and from then on you'd be saving $31 a year.

D. LIGHTS PRODUCE HEAT ENERGY

Lights use electrical energy to make light, but most of the electrical energy goes into making heat. The light energy that is produced in the lamp strikes objects in the room and is eventually converted into heat energy. So in the end, you could say that all of the electrical energy used in lighting fixtures winds up as heat energy. In the winter this is good because it helps to heat your home. If you have electric heat, it does not cost you any more either. Electricity is electricity; it does not matter whether you heat your home with electric baseboard heaters or light bulbs -- it costs the same either way. If you have oil or gas heat that costs less than electric heat, you can at least console yourself with the fact that the lights are helping to heat your home, although somewhat more expensively.

In the summer, however, it costs money to remove heat energy with air conditioning. In this case, you do not need the extra heat energy contributed by the lights in your house. For each watt of lighting power, you are generating about 3.4 BTU of heat energy that your air conditioner must remove. A 100-watt bulb thus creates 340 BTU of heat energy.

Now that you are aware of heat given off by lights, discuss the use of certain lights in your home which add unnecessarily to your air conditioning in the summer.

What could you do about this to cut down on lamp heat?

Each lamp in your home adds its heat energy, running up your electric bill as it lights your house -- and as it heats your house. In fact, all of your electric appliances produce heat energy that must be removed by your air conditioner.

Of course, you cannot stumble around in your house with all the lights turned off. You need lights to see what you are doing. You need lights to read, to work, to play, even to watch television in order to cut down on the glare. The trick, though, is to use lights effectively so you do not waste electricity. This calls for a little planning and common sense. You need to have lamps positioned in the right places. You need to have light switches in convenient locations. But most of all, you need to have the right amount of light for the type of work or recreation you are doing. Light levels that are too low will strain your eyes, and too much light simply wastes electricity.

MODULE #5

LIGHTING CONSERVATION OPPORTUNITIES

UNIT 2

ESTIMATING LIGHTING REQUIREMENTS

OBJECTIVES: At the completion of this unit the student will be able to:

Calculate lumen requirements and light bulb recommendations for various locations or task activities.

LECTURE

The unit of illumination is the foot-candle, which originated as the amount of light falling on a surface placed one foot away from a lighted candle. In recent years this unit has been replaced by the candela, but most literature still uses the foot-candle. A light bulb produces light energy that is measured in lumens. If one lumen of this light energy falls on one square foot of surface, the surface is said to have an illumination level of one foot-candle.

Stores, factories, and office buildings typically have illumination levels of 100 foot-candles or more and have drawn much criticism lately because it is more light than necessary. Figure 2.1 lists the typical amount of light needed in various rooms for performing different tasks.

LABORATORY

FIGURE 2.1. RECOMMENDED LIGHTING LEVELS

LOCATION OR TASK	FOOT-CANDLES
bathroom, general area	5
bathroom, at mirror	40
bedroom, general area	5
bedroom, at mirror	20
church, auditorium	10
classroom	30
closet	20
dining room	5
garage, storage area	10
garage, work area	50
hallway or corridor	5
ironing	100
kitchen, general area	10
kitchen, work area	40
living room, general area	20
office, service area	10
office, file work	30
office, close visual work	50
reading, short periods	20
reading, long periods	40
sewing, light fabrics	40
sewing, dark fabrics	120
stairway	10
utility room	10
writing	20

The number of light bulbs needed to achieve these general lighting levels varies with the type of fixture used and the coloring of the walls, floors, draperies, and furniture in the room. A formula to use for finding the number of light bulbs needed in an average room is

$$\text{number of bulbs} = \frac{2 \times \text{foot-candles} \times \text{floor area}}{\text{lumens per bulb}}$$

For example, in a 12- by 15-foot living room, the floor area would be 180 square feet. From Figure 2.1, the desired illumination level is 20 foot-candles. If 100-watt incandescent bulbs are used, each bulb would emit 1710 lumens. The number of the bulbs required in this case would then be

$$\frac{2 \times 20 \times 180}{1710} = 4.2 \text{ bulbs}$$

Pick any area in your home and compute the recommended lumen requirements for that area based on the type of activity which takes place there.

Is the present lighting adequate or unnessary for the activity?

Discuss the measures you could take to correct the situation.

Therefore, the need would be approximately four 100-watt bulbs. Depending upon the type of fixture, the placement of the lamps in the room, and room colors, the need for more or less light, but at least you have a good starting point. If the bulbs were covered with a lamp shade, and the floors and furniture were medium to dark colors, you might need two or three times as many bulbs to achieve a satisfactory lighting level. Light colors will increase the lighting level by reflecting and bouncing light around the room; dark colors will absorb light.

If you are going to work close to the lamp, you will not be interested in the general level of light in the room. For example, you may be using a floor lamp or desk lamp for reading or sewing. The light level obtained directly from a bare light bulb is obtained from the formula

$$\text{foot-candles} = \frac{\text{lumens per bulb}}{12 \times \text{distance squared}}$$

For example, if you were reading a newspaper located 3 feet from a 100-watt bulb (1710 lumens), the light level would be

$$\frac{1710}{12 \times 3 \times 3} = 15.8 \text{ foot-candles}$$

Normally, the lamp would have a shade that would help direct the light, so the amount of light falling on the newspaper would be increased to about 20 or 30 foot-candles.

Note that the amount of light striking a surface decreases as the square of the distance; that is, the distance

times itself. This means that when you move twice as far away from a source of light, you will receive only one-fourth as much light. Similarly, if you were only half as far away, you would receive four times as much light. To put this fact to work for you, consider a 30-inch-high table standing below a flush-mounted ceiling fixture in a room with an 8-foot ceiling. In this common situation, the light level on the table top will be about twice as much as at floor level without the table.

MODULE #5

LIGHTING CONSERVATION OPPORTUNITIES

UNIT 3

TIPS FOR BETTER LIGHTING EFFICIENCY

OBJECTIVES: At the completion of this unit the student will be able to:

Discuss lighting conservation tips and apply them to actual situation.

LECTURE

The following Institute of Environmental Studies recommendations for the better utilization of energy expected for lighting is a generally accepted standard for lighting design and use. It will serve as a capsulization of tips on lighting the student will find helpful.

1. Design lighting for expected activity. Light for seeing tasks, with less light in surrounding non-working areas.

2. Design with effective lighting fixtures and windows and skylights. Electric lighting and window lighting effectiveness depends on how well the light provided enhances the visibility of visual tasks. Light from either source, if not controlled, can reduce visibility by producing veiling reflections (reflections which will partially hide the details of a task and lower the task contrast) and disability glare (light scattered in the eyes producing a haze to look through -- such as experienced with oncoming headlights at night).

Discuss each of these items as they pertain to examples students can give for their particular situations.

Differentiate between household use and commercial use.

It has been found, for example, that lighting from the side by electric lights of specific design can enhance task visibility by reducing veiling reflections. Conversely, a heavy concentration of light from overhead and forward of the task can produce a high degree of veiling reflections.

Well shielded (low brightness) luminaires can eliminate disability glare.

3. Use efficient light sources (higher lumen/watt output).

For incandescent lamps, higher wattage lamps are more efficient.

40-watt general service produces about 11 lumens/watt input.

100-watt general service produces about 22 lumens/watt input.

Therefore in design consider use of fewer and higher wattage lamps.

For fluorescent lamps, longer length lamps are more efficient.

2 24-inch cool white lamps produce 50 lumens/watt.

2 48-inch cool white lamps produce 67 lumens/watt.

2 96-inch (800MA) cool white lamps produce 73 lumens/watt.

For HID lamps, (high pressures sodium and metal halide) higher wattage lamps are more efficient.

400-watt phosphor coated mercury produces about 46 lumens/watt.

1000-watt phosphor coated mercury produces about 49 lumens/watt.

400-watt metal halide produces about 74 lumens/watt.

1000-watt metal halide produces about 85 lumens/watt.

400-watt high pressure sodium produces about 100 lumens/watt.

For overall design, consideration should be given to the use of the more efficient sources such as fluorescent and HID.

4. Use more efficient bulbs. More efficient bulbs not only use energy more efficiently but also can reduce the user's lighting costs. For example, incandescent indirect bulbs may require a load of 10 watts per square foot of floor area to produce a 50 footcandle level, but direct fluorescent lights may only require a load of about 2.5 watts per square foot.

5. Use heat transfer fixtures. By using bulbs with air or water heat transfer capabilities, heat from fixtures can be exhausted before entering an occupied space in warm weather or conversely the heat can be utilized in the occupied space in cold weather. By integrating the lighting and air conditioning systems less room heating and cooling load should be required.

6. Use lighter finishes on ceilings, walls, floor and furnishings. Light finishes can increase the utilization of light. For example, by repainting ceiling, walls and floor and refinishing furniture, the average illumination level can be increased from less than 100 footcandles to over 40 footcandles.

In selecting light finishes, reflectances should be in the following range:

Ceiling Finishes..80-92 percent
Walls .....40-60 percent
Furniture.....26-44 percent
Office Machines &
Equipment.....26-44 percent
Floors.....21-39 percent

The upper limits have been selected to avoid excessively bright surfaces which can be uncomfortable or reduce visibility by producing disability glare.

7. Use efficient incandescent lamps. Higher wattage General Service lamps are more efficient than the lower wattage lamps. Therefore, using fewer higher wattage lamps may save power. For example, one 100-watt lamp produces more light than two 60-watt lamps (1740 lumens vs. 2 X 860 = 1720 lumens).

For the same wattage, General Service lamps (750 to 1000 hours life) are more efficient than Extended Service lamps (2500 hours life). For example, a 100-watt General Service lamp produces 17.4 lumens/watt input while a 100-watt Extended Service lamp 14.8 lumens/watt input. For equal lighting results in this case, 17.5 percent more lamps and power are required when using the Extended Service lamps.

Extended Service lamps are used where maintenance labor costs are high or where lamps are in inaccessible locations.

8. Turn off lights when not needed. When a working or living space is empty, secure and not used for display or observation, there is no need for lighting. In this case it

is always more economical to turn off incandescent lighting and, where off-time is more than a few minutes, fluorescent and high-intensity discharge lighting should be turned off.

In areas where adequate daylighting is possible, photoelectric control systems can be utilized to turn off the electric lighting.

9. Control window brightness. The requirements for good lighting design can be achieved by skillful application of daylighting techniques. These techniques include:

a. Redirecting available light for better interior distribution and utilization, such as with venetian blinds.

b. Limiting the brightness of fenestration to within comfortable limits (the same criteria as used for electric sources) by using devices such as: shades, screens, blinds, and low transmission glasses.

c. Controlling heat producing radiation entering a space by utilizing such means as reflective glass coatings and sun screening to reduce air conditioning requirements.

10. Utilize daylighting as practicable.

11. Keep lighting equipment clean and in good working condition. Studies have shown that good lighting maintenance procedures provide better utilization of the lighting system.

If better maintenance procedures are followed, it may be possible to reduce the wattage of incandescent lamps in a given system as long as adequate illumination is still maintained.

In designing new lighting systems more attention should be given to maintenance procedures and the consumer (tenant or owner) should be aware of the maintenance procedures considered in the design.

12. Be cognizant of planned operation and maintenance procedures. For building owners' and tenants' information, as consumers, all illuminated spaces should have a set of instructions covering the operation and maintenance of the lighting (electric or daylight), both for maximum utilization of power and for economic considerations.

MODULE #5

LIGHTING CONSERVATION OPPORTUNITIES

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Texas Power and Light Company

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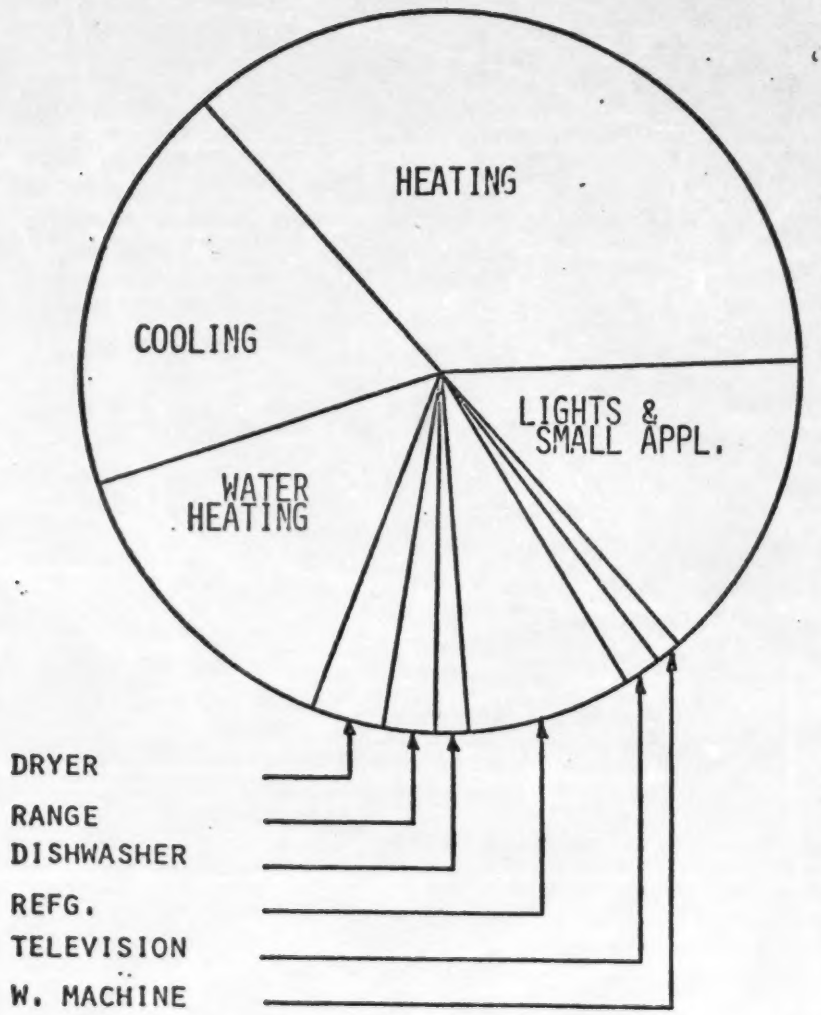
FIGURE 1.1

AVERAGE ANNUAL KWH
BY APPLIANCE



SOURCE: Texas Power and Light Company

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FIGURE 1.2. ENERGY EFFICIENCY OF VARIOUS LAMPS

WATTS	LUMENS	LIFE (HOURS)	(LUMENSWATT)
Incandescent Lamps			
40	435	1500	10.9
60	840	1000	14.0
75	1140	750	15.2
100	1710	750	17.1
150	2740	750	18.3
200	3940	750	19.7
Three-Way Incandescent Lamps			
50-100-150	560-1630-2190	1200	11.2-16.3-14.6
50-200-250	550-3560-4110	1200	11.0-17.8-16.4
100-200-300	1290-3440-4730	1200	12.9-17.2-15.8
Fluorescent Lamps (Cool White)			
15 (T8)	870	7500	58.0
15 (T12)	770	7500	51.3
20	1220	7500	61.0
22 (Circline)	950	7500	43.2
30	2340	15000	78.0
32 (Circline)	1750	7500	54.7
40	3120	15000	78.0
75	6200	12000	82.7

FIGURE 1.3 CHOOSING A LIGHT

	Incandescent	Fluorescent
Energy Use	Less efficient, produces more heat than light: 95% heat, 5% light.	Over 4 times as efficient as incandescent and lasts 7-10 times longer: 30% light, 70% heat.
Cost	Initial costs are less than fluorescent lighting.	Operating costs are less.
Versatility	Light can be adjusted by interchanging different wattage bulbs. Gain flexibility by using three-way bulbs and multiple switch controls.	Usually are stationary, ceiling-type fixtures that provide diffused lighting.
Best Use	For specific, close-in lighting: study, sewing room, bedroom, living room, or any area that requires light for reading and writing.	For general lighting: large work areas, bathrooms, laundry room, basement, kitchen, hallways, stairways, recreation rooms, or any large room where diffused light is required.

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FIGURE 2.1. RECOMMENDED LIGHTING LEVELS

LOCATION OR TASK	FOOT-CANDLES
bathroom, general area	5
bathroom, at mirror	40
bedroom, general area	5
bedroom, at mirror	20
church, auditorium	10
classroom	30
closet	20
dining room	5
garage, storage area	10
garage, work area	50
hallway or corridor	5
ironing	100
kitchen, general area	10
kitchen, work area	40
living room, general area	20
office, service area	10
office, file work	30
office, close visual work	50
reading, short periods	20
reading, long periods	40
sewing, light fabrics	40
sewing, dark fabrics	120
stairway	10
utility room	10
writing	20

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